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ANALYSIS OF SPACE SENSOR DATA

Andrew J. Mazzella, Jr.
Dennis E. Delorey

RDP Incorporated
391 Totten Pond Road
Waltham, Massachusetts 02154

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PHILLIPS LABORATORY
Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
HANSCOM AIR FORCE BASE, MA 01731-3010

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EDWARD C. ROBINSON
Contract Manager
Data Analysis Division

ROBERT E. McINERNEY, Director
Data Analysis Division

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Andrew J. Mazzella, Jr.
Dennis E. Delorey*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

RDP Incorporated
391 Totten Pond Road
Waltham, Massachusetts 02154

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This Final Report summarizes the major tasks accomplished under referenced contract.

RDP Incorporated, Waltham, MA functioned as prime contractor for these efforts, with the Institute for Space Research, Boston College, Chestnut Hill, MA as the major subcontractor.

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PREFACE

This Final Report provides descriptions of the major tasks accomplished under contract F19628-89-C-0079, Analysis of Space Sensor Data, for the period from 15 May 1989 through 14 November 1994.

RDP Incorporated, Waltham, MA functioned as prime contractor for these efforts, with the Institute for Space Research, Boston College, Chestnut Hill, MA as the major subcontractor.

In addition to the authors, other contributors of analytical, software and/or data processing support were: J.G. Casserly, P.E. Connolly, J.R. Cornelius, P. Dickson, J.R. Hughes, K.P. Larson and J.R. Palys of RDP Incorporated and K. Dieter, B.J. Donovan, N.J. Grossbard, K.R. Martin, W.M. McComish, C.M. Parsons, P.N. Pruneau and B.F. Sullivan of Boston College.

Cloud Analysis

Task Description

Develop cloud analysis software for the Phillips Lab (PL) VAX computer, based on Air Force Global Weather Central (AFGWC) software, utilizing new database interfaces.

The 'Best Reports' Total Cloud observation data for Day 85009 were identified and isolated from an AFGWC binary tape. The organization of the data was identified, and the data were unpacked and reformatted into a structured database on the VAX.

The RTNEPH analysis output for the Northern hemisphere for Day 85009 was unpacked and verified. This was reformatted into a structured database, and used to generate rudimentary displays of the Total Cloud field. Displays of data for Day 85009 were generated for comparison with the RTNEPH Total Cloud Analysis.

A modular dataset access protocol was designed, the goal of which is to enable a single Nephanalysis simulation program to operate on both 3DNEPH-style and RTNEPH-style inputs.

The cloud analysis software was developed and installed on the GL VAX. This implementation is based on the AFGWC program, but utilizes the new database interface for the 3DNEPH and RTNEPH data sets.

Rainfall Analysis - Percentage Rainfall Model

Task Description

Develop a model which predicts the percentage rainfall for particular sites, utilizing a large, existing database which consists of rainfall measurements at over 40 sites for a period of ten years.

The database for the tabulation of rainfall minutes for each individual month was constructed. This database consists of individual files for each of the rainfall stations, and was stored on a removable disk pack. The database was used to evaluate transmission outages for Boston and New Orleans throughout the year, and to evaluate the worst month conditions for over 40 rainfall stations.

Software was developed to apply regression analyses to the rainfall data to predict the percentage of time rainfall occurs. A set of functional forms for the different independent variables was incorporated into the software, and the initial set of regressions was evaluated. Except for extremely high or extremely low rainfall percentages, predicted percentages generally agreed with actual percentages.

A tabulation of the multivariate distribution for the cumulative distribution function (CDF) fit coefficients was performed, for the evaluation of functional forms to be used for that regression analysis. The tabulations were reviewed, and additional functional forms were incorporated for both the percentage rainfall and CDF fit coefficient regressions. The additional functions produced notable improvements in the extremes of the percentage rainfall predictions.

An expanded set of functional forms for the different independent variables was later incorporated into the regression program, based on further examination of the multivariate bin tabulations for the percentage rainfall and the cumulative distribution fit coefficients and an examination of the residuals for the percentage rainfall. Regressions for these were evaluated, and the agreement of predicted percentages to actual percentages was markedly improved.

The standard deviation in percentage rainfall for individual months over all years in the rainfall database was evaluated and compared to the individual errors in the regression model predictions. The comparison was quite favorable for the regression model. The standard deviation of the error of the model prediction was also evaluated, as was the fractional error in the model prediction. The latter appears to be a more representative measure of the model error.

The model prediction for percentage rainfall was compared to the actual values for the reserved rainfall stations, which were not used for the regression development. The standard deviation in percentage rainfall for individual months over all years in the rainfall database was evaluated for the reserved sites and was compared to the individual errors in the regression model predictions. As with the developmental stations, the comparison was quite favorable for the regression model. The standard deviation of the error and the fractional error of the model prediction were also evaluated for the reserved stations.

The model assessment for the cumulative distribution function was also performed, using plots of the model prediction versus the cumulative distribution function data, but the slope and intercept values were not separately compared to the model predictions.

Documentation describing the percentage rainfall and cumulative distribution function model development process was written. In addition, we developed user-oriented software for the climatological precipitation models. A demonstration of this software was given to PL personnel, and a brief descriptive document was prepared.

Publications

P. Tattelman, K.P. Larson and A.J. Mazzella, A Climatological Model for One-Minute Precipitation Rates, (to be published).

Rainfall Analysis - Duration Model

Task Description

A large database consisting of rainfall measurements at over 40 sites for a period of ten years is being used to develop models for rainfall occurrences. Using this database, develop a model which predicts the duration of rainfall for particular sites.

Software was designed for a rainfall duration climatological model to predict the number of occurrences of rain in a month, above a given threshold and time duration. Coding and testing of the Duration versus Frequency (DvF) software to tailor the processing to the rate selection scheme, and to allow specification for use of statistical data weighting and inclusion or exclusion of one-minute duration data in the quadratic fit processing, was completed. This DvF software was run for all regression stations, utilizing the statistical data weighting and omitting the one-minute duration data. Plots were generated of the shift values resulting from the correlated quadratic fits versus the associated rainfall rates, for each of the regression stations.

Alternative functional forms for the climatological regression model occurrence fits were explored, and a modified exponential function was utilized as the basis for alternative fits. Software was written to test this algorithm and the suitability of the model on a selected set of data. The non-linear fitting algorithm was then algebraically reduced to one non-linear equation, with the reference duration as its single variable. In addition, a method was devised to calculate lower and upper search boundaries around the root of the equation. Fits for the Pittsburg test cases were run and accepted, and data from the remaining 33 rainfall regression stations were processed. A report describing the derivation of the modified exponential model and the procedures for fitting the model to the data was presented to the initiator.

Software was designed and implemented to plot the comparison of actual reference duration versus the climatological model predictions by individual months and locations. Plots were generated of actual versus predicted reference durations for each month for the 34 regression stations. Plots of excessive error occurrences were generated from the comparison of predicted to actual reference durations, displaying the occurrence variation for each calendar month at each of the 34 stations being used for the model development. Plots of a similar format were also generated displaying the variation of each of the basic climatological parameters (on a calendar month basis) for each of the 34 stations. These displays and other geographical and climatological characteristics were examined for possible explanations of the error occurrences in the reference duration model, but no significant causal phenomenon could be discerned. Further investigations have been suspended.

Rainfall Analysis - ADAM Model

Task Description

Evaluate the Air Force Dispersion Assessment Model (ADAM) for aerosol dispersions.

Requirements for the evaluation of the ADAM model were discussed with technical personnel, and the software and associated reference files were installed on a PC.

Review of the batch files, programs, and data files that constitute the modeling system, including a detailed structural analysis of the specification software (ADAM) and the dispersion software (DISPER), was completed. Specification segments were received, for inclusion with the ADAM source code during compilation.

Compilation, library editing, and program linking BATCH files were developed. A written description and a demonstration of BATCH file utilization were completed.

NephAnalysis Migration

Task Description

Migrate NephAnalysis software and database from the Phillips Lab (PL) VAX computer to the AIMS computer system.

The cloud analysis program was validated, for both the older 3DNEPH and the current RTNEPH data base formats.

The evaluation of the discrepancies between the RTNEPH Conventional Reports (input) and the Air Force Global Weather Central (AFGWC) NephAnalysis (output) for Box 45 was completed. All the irregularities were traced to specific causes, the AFGWC-supplied data was accepted as valid, and the GL RDMRG was treated as functionally analogous to the Conventional-report portion of the AFGWC Merge Processor.

The Conventional-report processor for the 3DNEPH data using the RTNEPH algorithm was completed, and its results were validated. These NephAnalysis software and data sets were transferred to the AIMS computer system and verified.

Documentation for the AIMS implementation of the NephAnalysis software and data sets was delivered. Also completed was the process of interfacing the RDMRG with the NephAnalysis Data Base (NDB) package on the AIMS. The databases and processing for ground-based observations and estimations of cloud cover ("conventional NephAnalysis") were transferred to the AIMS computer and integrated with the existing Meteorological database.

Publications

John R. Palys, Conventional-Report Nephanalysis, GL-TR-90-0207, Scientific Report No. 1, 1990, ADA230385.

Climatology

Task Description

Provide software and analysis support for climatological data received from Naval Research Lab (NRL).

Data sets of ozone and water vapor climatologies from NRL were processed to generate three-dimensional perspective displays of mixing ratio versus latitude and altitude.

Ozone and Water Vapor climatologies were obtained from NRL via VAXMAIL and were reformatted for subsequent plotting, file transfer and analysis. A set of contour plots spanning all latitudes for each month of the year was generated. Distribution and BACKUP tapes were prepared.

Data acquisition and display programs were developed or enhanced for application to the NRL climatology files. Plots were generated for a specified set of altitude and latitude profiles. Climatology files were transferred to magnetic tape for further distribution.

The meteorological data base on the AIMS computer was examined for a problem involving the data indexing. After modifications by Phillips Lab (PL) personnel, testing indicated that the problem has been resolved.

Imaging Spectrometer Analysis (GLO)

Task Description

Provide data analysis support for a shuttle-borne imaging spectrometer experiment designed to measure local and environmental optical backgrounds.

Meetings of the design, processing and analysis support groups were conducted, to define requirements for the analysis support and interfaces to the design and data processing efforts.

An assessment of the effort and schedule for adaptation of pointing determination algorithms was developed, and the availability of test data was determined. A detailed plan for the development of the GLO pointing determination software was devised. A Hierarchical Input/Processing Output (HIPO) design was generated for the GLO pointing determination software.

Star field matching algorithms were evaluated in terms of estimated memory usage and processing speed, and applicability to the GLO requirements. The software design and code development for the star field test generator was completed.

A modified superstructure design for the pointing determination, based on the requirements for user input, was completed.

Software was developed to display a star field using magnitude-related symbols and legends. The software had the option of displaying two star fields (observed and catalogue) per frame, each with unique symbols and legends. Plots of the test star fields were generated.

Operational tests for star field matching were performed to evaluate refinements to the algorithm and appropriate parametric values, and to assess computer time requirements.

Procedures were developed for:

(a) Display of the star fields.
(b) Performance of the star field matching.
(c) Assessment of star field matching results.

SPEAR-II Support

Task Description

Provide software development support for the SPEAR-II mission. Develop a SPEAR-II database and data access software for use by Phillips Lab (PL/PH) personnel.

Task objectives were defined and a preliminary data processing plan for the flight data was developed. Integration test data sets were received for analysis and for use in software development. Specific validation and data transfer programs were developed for the integration test and flight data. The test data sets were generated and archived on the Central File Storage System.

Software for converting the data sets into transportable form was developed. The Local Area Network was used to transfer the files and associated software from the VAX to the Silicon Graphics workstation.

Data access software was developed, with a restricted data type selection and a simple interface to provide immediate access. Later, an extended data type selection was developed, along with a more refined user interface, an expanded data type selection, and a full menu interface to provide data access. This software was demonstrated to the users, and the software and data bases were made available on the Silicon Graphics workstation.

Supplementary software for merging time sequences for specified data channels into a matrix format was developed. Final installation of the refined software was performed on the Silicon Graphics workstation.

Unfortunately, due to attitude control problems, the SPEAR-II booster was detonated by the range safety officer after launch.

Ionospheric TEC Modeling

Task Description

Ionospheric models are utilized to evaluate Total Electron Content (TEC) along specified lines-of-sight, for a variety of environmental conditions, observing locations and times of day. Particular model representations for utilization are the Environmental Technical Applications Center (ETAC) model, which is the current radar standard, the parametrized Utah State University (USU) dynamical ionospheric model and the empirical Trough model, which is to be developed within this effort.

In addition to developing the Trough model, develop a data base and display format (denoted as the sky-map representation), covering the entire observable sky hemisphere, for evaluation of TEC effects and for model comparisons.

In order to evaluate the ETAC model, the ETAC data and associated software were transferred to the Phillips Lab (PL) VAX computer and utilized to generate sample output listings and files. Documentation and data for the parametric representation of the USU dynamic ionospheric model were also obtained, and the parameter files and associated software were installed on the PL VAX.

The data structures and processing algorithms for the sky-map representation were defined and developed as software routines for utilization with the different ionosphere models, for various viewing conditions.

The ETAC ionospheric model software was incorporated into a program to generate sky-map data bases of Total Electron Content (TEC). Extended capabilities were incorporated into the display software which was developed for the data bases, to display TEC contours as functions of azimuth and elevation.

The empirical Trough model incorporated a gradual transition from background to trough conditions, to avoid discontinuous effects at the edges of the trough. Although the model exhibited many of the features of observed troughs, further parameter development was required. An algorithm was implemented for relating the trough column density to the local electron density. Interfaces for the initialization routine required by this algorithm were incorporated into the scanning, tracking, and contour software, which displayed contours of the ionospheric density at a specified altitude, in order to identify the parameters associated with the model. Parameters were selected to provide a reasonable representation of the vertical trough cross-section.

Trough Model A was defined and examined, for vertical, horizontal and temporal aspects. The amplitude of the trough was excessive, however, and a revised model, designated Trough Model B, was defined and examined in the same manner as Trough Model A. A third model, with an arched vertical density dependence, designated Trough Model C, was defined and similarly examined. The Trough model was to be used with particular scanning conditions to evaluate TEC profiles in time and elevation.

Software was developed to represent a composite model of the morning, afternoon, and night-time trough. The model was integrated with the sky-map generation routines, and sky-map displays for viewing conditions for the afternoon trough were generated for comparison to a similar sky-map for the ETAC model. A corresponding geographic map of this three-trough model was also generated.

Trough models based upon TRANSIT satellite observations were then used to evaluate TEC variations in time, elevation and azimuth, and for comparisons to the ETAC model. Software was designed and written to create three-dimensional surface plots of TEC versus magnetic latitude and local time, for utilization with the TRANSIT data, as well as displays of representations of TEC values on a two-dimensional map of latitude and local time. Comparisons of the three-trough model and the ETAC model were generated, for both difference and ratio modes. The Trough model was then enhanced to include a ninth-order Hermite polynomial representation for the column density profile across the trough and to add a functional form for the diurnal variation of the background ionosphere in place of the constant background previously used.

Software for processing TRANSIT data to generate the database to be used for statistical comparisons to the ETAC model was developed and tested. TRANSIT data sets were processed as they were received, and a statistics database was generated. Software to plot ETAC TEC predictions versus TRANSIT TEC measurements was developed, and included reference lines for error ratios, while also allowing selection of azimuth, elevation, and local time ranges for the data samples. Histogram software for assessment of the model TEC error, diurnal TEC 3D plots versus magnetic latitude and local time, and the TRANSIT pass map software were also created. In addition, a report describing the TRANSIT data processing and utilization of the ETAC model was prepared and presented.

The ETAC sky-map software was extended to allow selection of a TEC scaling option based on a reference slant path TEC value for a specified azimuth and elevation. Sky-maps were generated, for identical local times, using the trough parameters. Comparison sky-maps without troughs were also generated. Sky-maps of trough minus background differences were then generated from these results and reviewed. ETAC sky-maps, using the zenith TEC values from the comparison sky-maps for scaling, were generated for the same local times and then an ETAC-to-trough model ratio comparison sky-map was generated. Software to display measured TEC, model TEC, or ratios of the measured TEC to a model as a function of Universal Time or local time was developed and used for the evaluation of model representations and conditions for trough detection. The trough impact assessment, relative to the ETAC model, was concluded, with the generation of histograms based on the ETAC-to-trough model sky maps. Samples of the intermediate stages and all of the final results were presented to the initiator.

Programs and procedures for processing Global Positioning Satellite (GPS) data were reviewed for the purpose of evaluating measured GPS data with TRANSIT results. Software to translate GPS four-channel data format into a format compatible with the TRANSIT analysis programs was developed, as well as software to translate the GPS single-channel format. Refinements of the data sampling interval were established for incorporation into the translation software.

Single-channel GPS data for December 1991 were processed into TRANSIT format for the display of measured vertical TEC values, associated ETAC model values, and ratios. The December results were presented, with a discussion of the most notable features in the data. TRANSIT data for December 1991 were plotted versus latitude and time, to examine the correspondence to the GPS data and verify the presence of ionospheric troughs. The lack of temporal correspondence between the single-channel GPS data and the TRANSIT data for December 1991 prompted the processing of four-channel GPS data for the same period.

Certain computational features of the ETAC ionospheric modeling program were examined, particularly concerning the determination of the Ionospheric Penetration Point (IPP). Extreme variations in TEC were derived using the original method of determination, but a more realistic variation was obtained by a consistent use of the elevation for the slant path. The revised method was adopted for further evaluations, and personnel at Space Forecast Center were notified of the effect in the model.

A statistical evaluation of the ETAC model, using both GPS data and TRANSIT data, including versions of the statistical assessments and display formats, was presented. A baseline was defined for the processing.

The histogram and scatter plot programs were enhanced to allow acquisition and processing of data from up to 4 TEC statistics databases. Trial runs covering one week of data from each of four trackers were performed to estimate file sizes and run times for full months. Additional software was developed to merge an unlimited number of TEC statistics databases, to accommodate the multiple weekly databases generated to represent seasonal effects.

The TEC statistics databases for spring, summer, and winter of 1991 were generated. Plots of actual TEC measurements versus the revised ETAC model predictions for the autumn season were generated and reviewed with the initiator. Processing for the winter season was completed.

Scatter plots and error histograms generated from the four seasonal 1991 GPS databases were reviewed, particularly with regard to systematic variations in the ETAC model performance by season. Summary plots of the effect of the model updating procedure were also generated, to display the variation of mean model error, standard deviation error, and root-mean-square error versus time lapse since the model update.

An algorithm for calculation of the proposed trough detection parameter was designed, and the software was developed and implemented. Sample results were calculated and displayed for two GPS trackers located at Lerwick. A summary assessment was prepared and presented.

Publications

A.J. Mazzella, J.G. Casserly, M.B. Delorey and J.R. Hughes, Ionospheric Model Assessment Using TRANSIT Data, PL-TR-91-2162, 1991, ADA244455.

NASCAP CAE

Task Description

Investigate an existing software package, VEHICL, written for the POLAR analysis software, for the purpose of creating NASA Satellite Charging Analysis Program (NASCAP) - compatible software. Create NASCAP interfaces and building block routines. Develop a user interface and menu structure to support object definition, development and display. Utilize NASCAP software for charging analyses of SCATHA.

A VAX/VMS command procedure was developed to support user interaction with the object display software. The preliminary hybrid NASCAP object plotter was revised to successfully handle all valid test cases of different building block configurations. The main module for the satellite model definition software was developed to execute with NASCAP building block algorithms, and the design of the menu structure was completed.

A format for the materials definitions file was developed, to allow revisions or additions to the surface materials specifications. Associated software was developed to perform the conversions from and to the existing definitions format, and to revise or augment the new reference file.

Algorithms and software modules for the NASCAP building blocks were developed. These included: Tetrahedral Antenna, Boom, Slant Plate, Slant Antenna, Fill-Block, Rectangle Patch, Wedge Patch, Plate Antenna, Tetrahedron, Rectangular Prism, Quasi-sphere, Octagon, Solid Plate, Antenna Plate and Wedge building blocks.

Based on the results of the integration and testing (including SCATHA satellite representations), further refinements were incorporated into the building block definition modules. When refinements were completed, these modules were integrated with the analysis selection and file manipulation modules to create the complete object definition program, SATMDL.

The SATMDL software was demonstrated (on more than one occasion) at the Phillips Laboratory (PL) in conjunction with other Computer Aided Engineering (CAE) tools.

Source code files were later transferred to the user's MicroVAX computer. In addition, complete software documentation, including a design document and user's guide, were provided.

The NASCAP software was later used for charging analyses for SCATHA.

LIFE (LEAP3)

Task Description

Assist in development of a Data Management Plan for the LIFE rocket. Process sensor payload data and determine attitude and trajectory information associated with the rocket-borne LEAP3 vehicles.

LIFE meetings at Phillips Laboratory (PL) and Space Division, AZ were attended, documentation was reviewed and an overview on trajectory and attitude processing was written.

Several meetings were attended to determine the LEAP3 mission requirements and the Hover test requirements. As a result of these meetings, preliminary requirements were defined for LEAP3.

Software was written which extracts required telemetry parameters and processes calibration data.

The Hover test was successfully completed. Calibration constants and algorithms were received, along with the Hover Test instrumentation tape. After successful digitization, the process of reformatting the file was accomplished and the appropriate telemetry parameters were determined.

The final runs on the calibration of the Hover test data were made, and two files were generated: one of the raw PCM data used as input to the calibration procedure; the other of the final calibrated results. These files were converted to ASCII form, stored on micro-diskette, and mailed to Hover test personnel at the Boeing Company.

Celestial Backgrounds - IRAS LRS Database

Task Description

Develop a celestial calibration reference database from the IRAS Low Resolution Spectrometer (LRS) data.

Examination of the correspondences between the IRAS Low Resolution Spectrometer (LRS) data base and the combination of the Yale Bright Star catalog and the Smithsonian Astrophysical Observatory (SAO) catalog yielded correspondence for approximately ninety percent of the IRAS LRS sources. The correspondences were used to provide more precise positions for the reference sources.

Data acquisition routines for the IRAS LRS tape were developed to acquire all of the necessary infrared source parameters, as well as their spectra, for use in creating the calibration database. Software for generating and accessing the calibration database were also developed.

Procedures for correcting the IRAS source positions were developed to account for preference of the Smithsonian catalog over the Yale Bright Star catalog, and to incorporate the proper azimuthal convention for the correction vector. Utilization of SAO catalog data in conjunction with the IRAS LRS database was implemented by extracting position and spectral information from the SAO catalog tape. The SAO catalog positions were compared to the positions determined from the IRS LRS data, as stored in the database.

Celestial Backgrounds - VIPER Support

<u>Task Description</u>

Provide testing support and data analysis for the Visual Photometer Experiment (VIPER), for the January 1992 shuttle flight.

Testing support and data analysis were provided for the Visual Photometer Experiment (VIPER), for a January 1992 shuttle flight. Data from the VIPER alignment test were examined for star and planet sightings, for use in determining the relative alignment of the visual radiometer and the television cameras. The nine-track Sunstrand data tapes from the storage test and sky test were reformatted into the VIPER major frame block format. Time track listings of the reformatted data were correlated with the PDP-11 transcription listings.

The high gain visual radiometer data sequence from the sky test was plotted to examine the visual radiometer calibration pulses. The time track listing program was enhanced to report maximum visual radiometer levels for both gains and filter position for each major frame.

Processing of the sky test data to determine the relative alignment and calibration of the visual radiometer and television cameras (Xybion, Pulnix) was completed. Software was developed to acquire video time codes from the FRAME program and merge them with the corresponding audio channel data. The fine tuning of video time code evaluation parameters was completed, based on November 1990 and September 1991 sky tests.

Full scale data collection of audio channel data from a VCR tape was completed, using data from the September 1991 sky viewing test. The audio data were merged with the time codes derived from the video data.

The flight data VCR tape was received, and evaluations of the time code data were performed in preparation for post-flight processing. Plots of the ecliptic plane crossings were generated.

Satellite Accelerometers

Task Description

Provide overall analysis support for the Satellite Electrostatic Triaxial Accelerometer (SETA) experiment, to be orbited aboard the first Space Test Experiments Platform (STEP-1) as part of the Atmospheric Density Specification (ADS) mission.

A detailed Software Development Plan was prepared, describing the functional and coding requirements for the software system, including data format descriptions. Algorithms for processing and analysis were included in the plan as the efforts unfolded.

DRAG COEFFICIENT ANALYSIS

Based on available documentation, a representational model of the STEP-1 vehicle was developed, for the purpose of calculating thermospheric drag and torques. The calculations for torques due to cylindrical objects included the torque terms intrinsic to the cylinder, due to shear effects, following an extension of the torque analysis performed by Lee Sentman of Lockheed.

Preliminary results for drag and torques were calculated, including effects of vehicle rotation on the acceleration measurements and the vehicle attitude uncertainty. In addition, an error analysis was performed, based on direct measurements of the ambient density and winds, satellite mass, aspect area and drag accelerations.

SOFTWARE SYSTEM

Raw Data Processing

Software was developed for the raw data unpacking and validation. The software accommodated the temperature variation of the accelerometer calibration coefficients and the specification of a storage unit scale factor. The calibration coefficients were developed from the tables of scale factor as a function of temperature, in order to convert raw counts to accelerations.

The modules needed to read the VAX SMC raw data file were designed, implemented, and incorporated into the VAX version of the raw data checking program. The Space and Missiles Center raw data unpacking and checking programs were also implemented on a PC.

Filtering and Bias Determination

Algorithms for the Power Spectral Density (PSD) calculation and the data manipulation portions of the filtering algorithm were developed. Versions of the software were developed to run on both the PC and on the PL/VAX computers.

Orbital dynamics effects were reviewed, for consideration of the orbital ellipticity on the accelerometer measurements and the bias determinations, and the design for the bias determination software was developed. In addition, software for stacked line plots was developed as a basis for bias history plots.

Drag Coefficient, Density and Winds

The basic software for calculation of drag and torque for the STEP-1 model was developed, incorporating the coordinate transformations required for each of the surface elements and the cumulative tabulation of the drag and torque vector components. Orbital and rotating coordinate system dynamics effects were reviewed, for consideration of these effects on the accelerometer measurements. Numerical estimates were made for these effects, based on information for the satellite configuration and orbital profile.

Software was designed which incorporated the algorithm for jointly calculating densities and winds. Software support routines were developed, and algorithms for minimization with non-linear constraints were incorporated into the density and wind calculation algorithm.

In addition, density and wind estimation software was developed for use during the early on-orbit check-out period. Due to the lack of ephemeris, attitude and environmental information available during the check-out period, provisions were incorporated to calculate orbital positions based on a simple elliptical orbit model, a nominal track-aligned attitude and a linearized drag coefficient representation.

Software Demonstration

A demonstration was presented, displaying the performance of the unpacking, checking, filtering and PSD software on actual ground test data. A separate demonstration was given for the Quick-Look Density/Wind calculation software, for which synthesized data were used.

Early Launch Support

Travel was performed in support of the real-time post-launch analysis. Provisions were incorporated into the processing stream for time-sequence plots of the accelerometer data and also the preliminary density and wind analyses.

The launch was performed, but a second-stage failure necessitated the destruction of the launch vehicle and payload.

The STEP-1 database, software and processing document was prepared and submitted to the initiator.

Publications

F.A. Marcos and A.J. Mazzella, "Accelerometer Measurements of Density and Winds for ADS", Atmospheric Density and Aerodynamic Drag Models for Air Force Operations, GL-TR-90-0033, Environmental Research Papers No. 1053, 1990, Vol I: ADA220381, Vol II: ADA220382.

A.J. Mazzella and K.P. Larson, SETA/ADS Software Development, RDP-TR-9404, 1994, PL-TR-94-2279. **ADA291181**

Interim Terrain Model

Task Description

Develop a data processing design and software development plan for the Interim Terrain Model (ITM).

A preliminary investigation of the Interim Terrain Model development facilities was conducted, including mapping of terrain into the viewing field.

Technical meetings were held with the initiator regarding receipt of the Digital Terrain Elevation Data (DTED) file for the Hanscom AFB area, and the format of the data within the file. Software to convert the DTED data to an ITM compatible format was received.

Discussions were conducted with the initiator regarding parameters for the DTED storage and formats of intermediate terrain files currently utilized for evaluating terrain scenes. Code development requirements were addressed. Information was obtained about the sensor, to which synthesized scenes will be compared.

A processing design and software development plan was developed, and considerations of the terrain viewing geometry were incorporated into the plan.

The processing design and development plan was delivered to the initiator.

TEC Model Correction Factors

Task Description

Develop a Scale Factor Generation (SFG) software system, utilizing real-time ionospheric observations performed by the Ionospheric Monitoring System (IMS) and parameters supplied by Air Weather Service (AWS), to generate correction factors for Total Electron Content (TEC) model values used at the observation site.

The process of migrating the TEC modeling software from the VAX to a PC involved emulating VAX/VMS and IMSL functions and subroutines, and translating reference databases received from Space Forecast Center (SFC) into formats supported by the Microsoft FORTRAN, with associated program changes for data access. The weighting method for TEC measurements was developed and incorporated into the design for the driver portion of the Scale Factor Generator (SFG) software, together with operational enhancements and a data interchange method.

Support files for the ionospheric model were sent to the University of Texas for their IMS developmental efforts, and an IMS simulation program and simulation reference file were received from the University of Texas for testing of enhancements to the PC/Windows-based Scale Factor Generator (SFG) software. The enhancements included time labels for messages displayed on the PC screen, modified and augmented data quality checking criteria, more descriptive error messages, and capabilities for run-time assignment of operational parameters. The latter capability was incorporated to allow later adjustment of the measurement weights, elimination of measurements associated with particular satellites, and operational refinement of warning thresholds. The enhanced SFG software was demonstrated and sent to the University of Texas for evaluation and integration with the IMS software.

An SFG overview document and operator instruction document were prepared and sent to the University of Texas for incorporation into the system documentation. These documents were incorporated together with instructions concerning ancillary software, the enhanced software design, and annotated simulation results to create a technical report for the SFG software. In addition, remote support was provided for the installation of the SFG software at Shemya and the initial operational and procedural performance evaluation.

Discussions were conducted with Space Forecast Center (SFC) personnel regarding the elevation assignment standardly used in ionospheric penetration point calculations for radar sites, for a variety of programs developed for Global Weather Central (GWC), the Environmental Technical Applications Center (ETAC), and SFC, and which have also been incorporated into the Scale Factor Generator program. A possible replacement assignment, as developed for a local implementation of the ETAC program, was also discussed.

A study was conducted regarding the utilization of the Scale Factor Generator program in conjunction with processed GPS data to perform off-line calculations of correction factors for statistical evaluations. A simulation case implementing one possible technique was processed for measured TEC data from October 1992. The results of this case, together with the diurnal TEC profile derived from the PC version of the Space Forecast Center modelling program, were presented for evaluation. Additional software was developed to plot the actual scale factors recorded in the SFG TEC log file, for use as an overlay to the plots of TEC versus time, and to display the time-occurrence pattern for the various satellites observed each day.

Two programs were developed to implement processing of stored GPS data for TEC correction factor evaluation, in a manner analogous to the real-time Scale Factor Generator. The first program converted the available data into 15-minute average samples, with appropriate coordinate assignments and quality validation, while the second program, based on the original Scale Factor Generator, acquired concurrent sets of 15-minute average samples and calculated the corresponding TEC model values to evaluate the correction factors.

Existing software, which converts GPS RINEX (data exchange) format data into simulated single-channel format was reviewed, and a number of enhancements were incorporated. Provisions for incorporating additional simulated trackers were generalized to facilitate extension to up to 99-trackers, for the two data types required. Additional report files were generated by the conversion program, to report on the tracker assignments for each satellite and on the satellites observed for each time sample. Auxiliary software processed these report files to provide summaries of the tracker assignments, to check for overlap in observation periods for the different satellites, and to report percentages for observation time for each satellite. Further provisions to assign satellites to specific trackers were added to the conversion program, and a sample assignment table was prepared based on the reports from the auxiliary programs. Test cases for the various operating modes were run, using preliminary data from JPL. Demonstration of the software was also performed.

A self-consistent GPS bias determination method was drafted and presented to the initiator. An outline was developed to describe the adaptation of existing programs for the development of Ionospheric Penetration Point (IPP) databases, used for the determination of GPS bias values. Software was developed which generates Ionospheric Penetration Point (IPP) databases, and analyzes the IPP databases to determine the bias values for the individual GPS satellites.

Software to perform the GPS bias determination was completed, and tests of the software to generate Ionospheric Penetration Point databases and determine GPS bias values were performed. To assist in the evaluations, software was written to plot the projected path of the GPS satellites (as Ionospheric Penetration Points) together with the original or derived TEC values (following the application of the bias corrections). These tests lead to the appropriate selection of restriction parameters and convergence criteria, producing excellent representations of the diurnal TEC profile and consistent results independently of initial bias estimates.

Further tests were conducted, to investigate the effects of sparse sampling of the data (for decreasing the calculation time) and alternative latitude selection ranges (for including additional satellites). Software was developed to examine TEC data files for time gaps, which were associated with discontinuities in measured TEC levels, and to partition these data sequences into separate files without time gaps or TEC discontinuities, for readjustment in subsequent processing. This program was augmented to evaluate the uncertainty in referencing relative slant TEC measurements to noisier absolute slant TEC measurements, and was incorporated as a preliminary stage in the bias determination process.

An Ionospheric Penetration Point (IPP) database generation program was developed to process GLONASS or TISS data formats, to create databases for use in the bias determination processing. A utility pre-processor program for the IPP database generation procedure was also developed, to automate data specification preparations for processing.

A single day of GLONASS data was processed for bias determinations and the diurnal ionospheric profile. Some unusual characteristics of the GLONASS data required additional preparation for the bias determination processing, and development of a plotting routine for data evaluation. GPS data for the same day were acquired for the Royal Observatory in England, and were processed to generate an ionospheric profile for comparison to the GLONASS data. In addition, a sample day of TISS data was processed for bias determinations and ionospheric profiles.

Publications

A.J. Mazzella, Scale Factor Generator Program for Ionospheric Model Corrections, RDP-TR-9201, 1992.

G. Bishop, D. Walsh, P. Daly, A. Mazzella and E. Holland, Analysis of the Temporal Stability of GPS and GLONASS Group Delay Correction Terms Seen in Various Sets of Ionospheric Delay Data, ION GPS-94, 1994.

HILAT/Polar Bear - Archive

Task Description

The HILAT and Polar BEAR satellites archive efforts involved the automated logging, copying and quality checking of summary and raw tapes received from various receiving stations, and the creation of CDC forms of the summary tapes.

The charts below reflect the summary copy status of data for each satellite.

HILAT:

Station	No. of Tapes	No. of Passes
Tromso	269	5380
Rover	79	3160
Sondre	131	3275
Churchill	229	5725

Polar BEAR:

Station	No. of Tapes	No. of Passes
Tromso	208	7072
Rover	29	870
Sondre	161	3864
Churchill	51	1530

CRRES Analyses

Task Description

Provide support to the development of the CRRES Time History Data Base (THDB) Data Management Plan (DMP). Develop software and associated analyses for the generation of the CRRES THDB.

Several meetings were held with CRRES researchers at outside agencies to obtain details concerning processing of data from various CRRES experiments. Appropriate sections of the THDB DMP were written as a result of these meetings.

A description of the CRRES THDB was prepared and presented to the CRRES Science Team Meeting at Ball Aerospace in Boulder, CO. THDB pre-process software for the following experiments were developed:

(a) Proton Telescope
(b) High Energy Electron Fluxmeter
(c) Medium Energy Electron Spectrometer
(d) MOS Dosimeter
(e) Electron-Proton Angle Spectrometer
(f) Proton Switch
(g) Relativistic Proton Detector
(h) Search Coil Magnetometer
(i) Passive Plasma Sounder
(j) Low Energy Magnetospheric Ion Composition Sensor
(k) Heavy Ion Telescope
(l) Low Energy Plasma Analyzer

Associated access routines were developed to aid in file verification and the verification of data stored on Agency tapes. In developing these software, many meetings were held with researchers, including trips to University of Chicago, University of California (Berkeley), Palo Alto (Lockheed), and San Diego (CRRES Science Team Meetings).

Calibration information for the conversion of THDB parameters to science units and modified decompression algorithms for use with the 12-bit and 8-bit sensor readouts were examined. In discussions with the CRRES Science Team PI, it was decided to leave the THDB data for certain sensors in compressed form. Modified file structures were defined and the computer code modifications were completed.

Presentations concerning the status of the pre-process software for each sensor to be included in the THDB were prepared and presented at quarterly Science Team meetings.

Telescope Leakage

Task Description

Provide software support for HIRIS telescope leakage determination.

Modifications were made to the software which calculates leakage from theoretical models of the point source rejection. The modifications allow different point source rejection values for different directions, in particular, vertical and horizontal. A set of data was provided for the horizontal and vertical directions, and plots were made showing the results for telescopes consisting of the horizontal model in all directions, the vertical model in all directions, and the direction dependent model. The direction dependent model was then used to process data for various altitudes and frequency ranges.

In addition, software, in which estimates of the PSD (Power Spectral Density) implied by interferometer measurements were used to find a point source rejection model to approximate the results, was updated and rerun to obtain a better model of the point source rejection.

Offaxis Radiance

Task Description

Provide analysis and software support for offaxis radiance calculations.

The software which evaluates and plots sensor offaxis response functions parametrized according to the Dowling model was enhanced to incorporate the effect of the sensor baffle on the aperture diffraction. Only slight differences were observed in the models being evaluated.

The software which plots infrared flux on concentric zonal regions for the sensor field-of-view was upgraded to NCAR version 2. The software which plots cumulative offaxis flux, based on the results of offaxis radiance calculations, was upgraded to NCAR version 2 from NCAR version 1.

Offaxis response characteristics for a new sensor were converted into the standard format for graphical display and future offaxis radiance calculations. Plots were generated of the sensor offaxis responses along the horizontal and vertical axes of the sensor field-of-view.

BEAR Analysis

Task Description

Provide software and analytical support for the Beam Experiment Aboard Rocket (BEAR) mission. Process raw data and trajectory tapes, including unpacking, quality checking and data conversions. Determine mission attitude.

Phase I - Raw Data Processing

Five digital raw data tapes were received and quality checked. Due to time code discrepancies on all tapes, we requested the tapes be redigitized. Three new sets of digital tapes were created and quality checked, with the last set finally being acceptable.

This last set was used to extract selected parameters and create a data file to be used for attitude determination.

Phase II - Trajectory Data Processing

Five (5) trajectory tapes (3 payload and 2 sustainers), each containing two ASCII files of radar data, were received. Unpacking software was developed and trajectory data bases were created.

After evaluation, Radar 113 was chosen as having the best quality data for the entire flight. A double Kalman filtering technique was chosen to create the data base. Using the processed trajectory data from radar 113, the known initial radar parameters, launch and vehicle conditions, a final trajectory report was generated, and detailed graphical displays of calculated values were created.

Phase III - Attitude Determination

Evaluation of the processed raw data tapes indicated a discrepancy in the sample rates of the vehicle's attitude control system and the main telemetry link. In addition, examination of magnetometer data indicated that the three magnetometers were being influenced by a permanent magnetic field. When these anomalies were corrected and the final raw data files and trajectory were created, vehicle attitude was calculated.

VAX-compatible tapes of attitude data were created and sent to three agencies for their use. A final attitude report was submitted.

Scintillation Analysis

Task Description

Requirements for the HILAT and Polar BEAR satellites scintillation data included the fitting of the phase and intensity data over fixed frequency bounds, capabilities for the spectra and fit displays, displays of fit coefficients, and extraction of selected magnetic, ephemeris and other vehicle parameters for correlation with the scintillation data. In addition, follow-on statistical applications were performed over the lifetime of the vehicles on a three-month basis.

Scintillation outputs for both HILAT and Polar BEAR were successfully generated. They included data through the following days:

Station	HILAT	Polar BEAR
Sondre	day 146, 1989	day 153, 1989
Tromso	day 180, 1989	day 177, 1989
Rover	day 003, 1989	day 012, 1989
Churchill	day 090, 1989	day 195, 1988

Follow-on statistical requirements included sorting selected parameters in each data base into bins based on elevation angle, K_p values, magnetic local time, and invariant latitude. The required statistics were then stored on permanent file. For each data base created, representative listings of the statistics associated with selected scintillation parameters and selected summary science parameters were created for 2-hourly and 1-hourly magnetic local time bins. In order to display the magnetic field line through the E-region penetration (100 km) and the F-region penetration (350 km) on selected plots, permanent files of the associated geodetic latitude and longitude as functions of time (every 15 seconds) were generated for selected time periods.

Nineteen 3-month HILAT scintillation statistical data bases were created, covering the period November 1983 through June 1989. In addition, fourteen 3-month Polar BEAR data bases were created covering February 1987 through March 1990.

Data bases associated with several experiments flown on the HILAT and Polar BEAR satellites were created and subsequently correlated with scintillation data to assist in various scientific studies. The experiments involved include the UV Imagers, the HILAT Ion Driftmeter, the HILAT J/sensor, and the HILAT Magnetometer. Associated plots and listings of selected parameters data were generated.

The scientific studies which utilized these data bases included:

(a) Overflights of the Sondrestrom radar which identify magnetospheric boundaries, by utilizing HILAT J/sensor data. Ground-based observations of such boundaries were provided by the incoherent scatter radar (ISR).

(b) Poynting fluxes were computed utilizing HILAT electric and magnetic field data for comparison with Joule heating observations, as obtained by the ISR measurements.

(c) Polar BEAR UV images were compared with near simultaneous HILAT J/sensor data for modeling electron density profiles in the E-region.

(d) HILAT J/sensor data obtained during overflights of the Tromso Heating Facility were utilized to study wave-particle interactions caused by high power radio waves.

(e) HILAT electron density and electric field data were spectrally analyzed to determine instability mechanisms creating plasma structuring.

(f) Statistical analyses of HILAT electron density data were made in order to understand seasonal behavior of scintillations and total electron content measurements at Tromso, Norway.

UV Processing

Task Description

Provide support of ultraviolet data obtained from sensors flown on-board orbiting platforms.

A preliminary version of the PC-hosted spectrogram software was developed. The software generates false-color displays of electron and ion spectra as a function of time and magnetic latitude, for time spans ranging from one minute to 24 hours. For time spans longer than one minute, spectra are averaged to enable their display on a standard VGA screen. The standard deviations of the electron and ion data are also computed and displayed. Once a false-color representation has been displayed, the user, via mouse directed input, may plot energy spectra at any desired time, or produce time-series displays of sensor outputs for desired energy channels. These displays may be printed on a variety of hardcopy devices. The software displays spectra data in raw counts, as a function of magnetic latitude.

A demonstration of the software and of the resulting imaging was prepared. The data set displayed was the DMSP SSJ/4 electron and ion spectra data as a function of time and ephemeris from the DMSP SSJ/4 sensor. The images were used for comparison with corresponding Polar BEAR AIRS image data. The spectra data were collected on-board the DMSP F7 vehicle and covered selected periods of interest during January and February of 1987.

As a result of the demonstration, the software was enhanced to include the capability to display data in physical units (fluxes, energy densities, etc.) as well as raw counts; the capability for keyboard input of the time tags to access and plot spectral data; and a color print format of the false-color displays. The spectrogram software and relevant data sets were then installed on the PI's PC system, and the software package was again demonstrated.

The DMSP charged-particle display software version, which exhibits electron and ion spectral data from the DMSP Electrostatic Analyzer instruments, was enhanced to meet additional user requirements. The software can create and store spectral data in an ASCII file for subsequent use; it can tabulate the full set of ephemeris data to a file, for any user-specified time interval; four additional alternate axes (magnetic latitude and longitude, magnetic local time, and geographic latitude and longitude) were added; and the spectral plots were annotated with an expanded set of ephemeris parameters.

A brief user document to accompany the DMSP Charged-Particle Display Code was written, and a demonstration of the enhanced software package was given.

DMSP Analysis for Sensor Data Base Generation

Task Description

The task consisted of creating and maintaining processed data bases for the Defense Meteorological Satellite Program (DMSP) for the SSJ/4, SSJ3, SSJ*, and the SSIES experiments flown on-board the F6, F7, F8 and F9 vehicles over their respective lifetimes. Of the four satellites, only F8 and F9 were active. Data processing systems and associated software were developed, updated and maintained for each of the various experiments.

The J/4 data base was created for the periods December 1982 through 22 July 1987 for the F6 vehicle, November 1983 through 25 January 1988 and 25-26 April 1988 for the F7 vehicle, 25 June 1987 through 15 September 1990 for the F8 vehicle, and 8 February 1988 through 15 September 1990 for the F9 vehicle. Microfiche displays were generated for the above time periods for the four vehicles with the appropriate calibrations.

The SSIES data base was created from 25 June 1987 through 20 August 1990 for the F8 vehicle and from 8 February 1988 through 20 August 1990 for the F9 vehicle.

For the J* instrument, F7 data bases were created for the periods, November 1983 through 25 January 1988 and 25-26 April 1988. Microfiche displays were generated. In addition, the J3 data bases were created for the period, September 1977 through 28 February 1980.

In order to backup the J/4 data bases on optical disk, a computer program was developed to restructure the data bases into a VAX-compatible format. The data bases were stored on magnetic tape prior to optical disk storage.

The first 34 months of F8 data were restructured onto magnetic tapes in a VAX-compatible format, for subsequent transfer to optical disk.

Due to the unique blocking of the F6 and F7 J/4 data bases, it was necessary to develop a front-end program to regenerate the original data base tapes into the format required by the restructuring program. The F6 J/4 data was then reformatted over its entire lifetime. The F7 J/4 data was also reformatted over its entire lifetime.

J/4 F7 counts rates were accessed to produce computer-generated listings and plots of differential number flux as a function of time and energy for both ion and electron data over various time periods. Also, similar listings of computed distribution function for both ion and electron data were generated.

Optical Turbulence - F-Model

Task Description

Use atmospheric models to attempt to model a parameter which relates CN^2 to quantities of velocity, pressure, time, zenith angle, humidity and temperature. This parameter, designated as F, seems to best be described as a constant ("A") up to the end of the troposphere and as the constant plus a term consisting of another constant ("B") times the distance above the troposphere squared. This effort was directed towards finding a way to predict "A" and "B".

Models involving each possible parameter used in a series expansion to predict "A" and "B" were studied. From the studies, it was determined that, except for the zenith angle, the parameters, if used in the prediction, would only be used in a linear form.

A sinusoidal fit of the zenith angle plus one of the other parameters used to predict "A" and "B" was developed. Parameters were added to the tables which consisted of the difference in temperature divided by the difference in altitude between the beginning and end of the troposphere and a similar value between the highest altitude available and the top of the troposphere and these ratios plus the value of gravity.

The tables were reviewed for consistencies, and combinations of parameters which give a "good" fit and provide some theoretical sense were selected. Software was written to create a file containing the models for "A" and "B", as follows:

<u>During the day:</u>

$$A = \text{constant} + \text{constant} * (dt/dz)_{\text{between}} + \text{constant} * (1/((dt/dz)_{\text{between}} + g));$$

$$B = \text{constant} + \text{constant} * \text{cosine}(Z_{\text{ang}} - 45) + \text{constant} * (t)_{\text{break}}.$$

Here,

$(dt/dz)_{between}$ is the temperature difference divided by the altitude difference between the top and the bottom of the troposphere;

Z_{ang} is the zenith angle;

$(t)_{break}$ is the temperature at the top of the troposphere;

g is the value of gravity.

During the night:

$$A = \text{constant} + \text{constant} * (t)_{lo} + \text{constant} * (1/((dt/dz)_{hi} + g));$$

$$B = \text{constant} + \text{constant} * (t)_{lo}/((dt/dz)_{between} + g)).$$

Here,

$(t)_{lo}$ is the temperature at the bottom of the ionosphere;

$(dt/dz)_{hi}$ is the difference in temperature divided by the difference in altitude between the highest altitude value of the data and the top of the troposphere.

These constants were determined by least squares fits, and the results were used in software to determine if they were accurate predictors of CN^2 from the data available. Several sets of data were run using the model "A" and "B" values. The results were encouraging. In addition, software was written to plot "A" and "B" values derived from the data versus the model estimates.

After much experimentation involving weighting the points used in the fit, and detecting and removing outliers, a new set of "A" and "B" values was found for all the data. Production runs were made to find "A" and "B" values for the CLEAR 1 experiment data profiles available.

A separate model for estimating CN^2 values, proposed by Dr. Edmond Dewan, was programmed, the resulting software was run with data from Penn State, and the results were compared to the above described model. From the comparisons, it was determined that the Dewan model should use estimates for shear rather than the estimates of the variability of speed squared in the model. This change was made in the software used to find a model of CN^2 versus altitude.

Optical Turbulence - Estimate CN^2

Task Description

Using atmospheric models, develop methods to estimate CN^2 and predict turbulence from data consisting of altitude, pressure, velocity and relative humidity. CN is the refractive index turbulence structure constant of the atmosphere. Related to CN^2 is C_T^2, which is the temperature index turbulence structure constant of the atmosphere. Theoretically, a necessary condition for turbulence to begin is that Richardson's number drop below 0.25. After such a drop, turbulence may start even if Richardson's number rises above 0.25.

A model, which involves estimating Richardson's number from the estimates already calculated of Brunt-Vaisalla's frequency (W_b) and the shear, was examined. From Richardson's number, a layering length (L_o) was estimated using estimates for the standard deviation of the velocity, and W_b. Finally, from L_o, W_b, T and g (T=temperature, g=gravity), an estimate of C_T was created. C_T is related to CN through the temperature and the pressure. Additional plots were added to the software.

By means of modeling turbulence in the atmosphere, attempts were made to find a relationship of temperature, pressure, relative humidity and velocity measurements to a small scale layering length (LS) calculated from CN^2 measurements. Towards this end, large scale layering lengths (LL) were calculated from the measurements for the troposphere and the stratosphere. Linear models of the logarithm of LS versus the logarithm of LL were then found from a least squares fit of 15 sets of data. The model was then run on each of the 15 sets of data separately, and the results were presented to the Initiator.

Two other models were developed to model small scale layering lengths (LS). The two semi-empirical models were:

$$\log(LS) = A_1 + B_1 \log(V) + C_1 \log(W_b + DW_1)$$

and

$$\log(LS) = A_2 + B_2 \log(V/\bar{V}) + C_2 \log[(W_b + DW_2)/\bar{W}_b]$$

where,

V is an estimate of the root mean square of (velocity minus an estimate of the average velocity),

W_b is an estimate of the Brunt-Vaisalla frequency,

the A's, B's, C's, and DW's are constants found by a least squares fit-type analysis,

the DW's themselves are values to correct for a possible bias in estimating W_b, and

$\bar{V}$ and $\bar{W}_b$ are the average values of V and W_b, respectively, for the particular data set being analyzed.

The two models were applied to the 15 Penn State data sets and to all appropriate data sets for experiments CLEAR 1, CLEAR 2 and CLEAR 3. In addition, the program was run for FLATLANDS data. The FLATLANDS data appeared to be well-fit by the models. This could be explained by the fact that the values of V and W_b were found by different instruments for CLEAR data than for Penn State data, whereas, the FLATLANDS data used instrumentation similar to that used for Penn State data.

The results of the latest models for estimating CN^2 (structure constant for the fluctuations of the optical index of refraction) from temperature, pressure and velocity measurements were to be compared to results from an earlier AFGL model. Both models attempted to estimate a small scale turbulence layer or "outer length" (L). The AFGL model was given as:

$$\mathrm{Log}_{10}(L) = -1 + 3/4\ Y(S)$$

where:

for the troposphere: $Y = 1.566 + 29.62\ S$,

for the stratosphere: $Y = 0.508 + 37.01\ S$,

and

S is the shear found from weighted average velocity values for selected altitude intervals of 300 meters.

This model was used in place of the newest models for CN^2 (or L) in the software designed to test the models for Penn State data. The results indicated that the earlier AFGL model was not as accurate as the latest methods of estimating CN^2.

A description of the models software was presented to the initiator.

Optical Turbulence - Simulate Atmospheric Effects

Task Description

Develop software to simulate atmospheric effects which have various PSD and/or autocorrelation behavior. For example, find linear predictors to estimate temperature fluctuations at a particular altitude from the values at neighboring altitudes.

We attempted to simulate two-dimensional random data whose A(t) autocorrelation and/or PSD (Power Spectral Density) approximated a given A(t) and/or PSD. Our approach was to find a finite impulse response filter which would lead to the desired A(t) and PSD. Our initial approach, using a weighted least squares, used a low order linear predictor found from A(t) values as a pre- or post filter, only fit the PSD above some given lowest frequency, and simultaneously fit the derivative of PSD with frequency as well as PSD. The results were encouraging.

Attempts were made to simulate data using the finite impulse response filter defined on all the points within a square (full plane filter) and then apply a finite impulse response filter to the result. The filters were applied to an initial sheet of simulated Gaussian random numbers. If the infinite impulse response filter was applied directly, it would involve solving N times N equations for N times N unknowns. In this case, the initial two-dimensional sheet is made up of a square of 512 x 512 points. This was impractical.

Therefore, in order to approximate the result of applying the infinite impulse response filter, we first applied four quarter plane filters and summed the result. The coefficients of the quarter plane filters were set so that their response curve approached the response curve of the full plane filter as the frequency (fx and fy) approaches 0. The parameters fx and fy are the frequencies for each of the two coordinates of the sheet. This was an initial approximation for the filtered results, and an iterative procedure was then used to improve this approximation.

The iterative procedure was to apply the full plane filter as a quarter plane filter would be applied. Each time the full plane filter was applied in this manner, it resulted in a better approximation. The actual logic used the full plane filter starting at each corner of the sheet, and then iterated to get a final approximation. Once completed, we applied the finite impulse response filter to the result.

The results of the simulation were then checked by estimating the two-dimensional Power Spectral Density (PSD) of the resulting sheet and by estimating the one-dimensional PSD along horizontal and vertical lines of the resulting sheet. The estimates indicated that the resultant simulated data's PSD approached the expected PSD as the number of iterations used in estimating the application of the infinite impulse filter increased.

CRRES Data Verification

Task Description

This effort involves the verification (and/or validation) of data sets and data types associated with the CRRES project.

Sample Agency files were verified for four periods of MEP/MOS (MicroElectronics Package/MOS Dosimeter) data acquired during testing. These files were checked for structure, time tagging, and proper minor frame word selection during Geosynchronous Transfer Orbit (GTO) mode operations. In addition, sample Agency Tapes (ATs) - one containing Passive Plasma Sounder and Searchcoil Magnetometer data, one containing three periods of University of Iowa data, and one containing an 8-hour period of Aerospace data - were similarly verified.

A full orbit of simulated Aerospace (GTO) CRRES data was verified. These procedures included verification of the header, ephemeris, magnetic field, attitude fit coefficient and telemetry files. In addition, four new data sets - the GTO Berkeley file, the GTO Internal Discharge Monitor, the GTO Solar Panel, and the LASSII Mass Spectrometer (QINMS) files - were verified.

A request for inclusion of the sun sensor data on the Solar Panel agency file was investigated. After study, it was determined that sufficient information existed to satisfy post-launch requirements.

A document detailing post-launch calibration procedures for the Science Magnetometer was received. After review, it was determined that the document was sufficiently detailed to provide users with the steps and techniques required for calibration.

Analysis of a University of Chicago data file had determined that the last byte of each data group was zero-filled in the decommutation process. Chicago personnel were informed, and a corrected Agency tape was created and verified.

Volumes of telemetry files for all GTO agencies were verified under GTO, LASSII and CSM telemetry modes. In addition, Header and Ephemeris files were consistently checked against data structure requirements. Flight data covering all combinations of modes were received and ATs were produced, as required.

A number of orbits of anomalous data were processed. The anomalies dealt with the VTCW jumps and corresponding frame counter re-alignments. Modifications to the flight software were made to correct these anomalies, and agency tape files, generated with the modified software, were validated. Several requests were received for the retrieval and display of selected parameters for periods during which anomalous commands were received aboard the spacecraft. These requests were satisfied.

ECHO-EPP Attitude

Task Description

Two tasks were accomplished:

(a) Determine the attitude of the ejected ECHO-EPP module using initial ejection conditions and a set of triaxial magnetometer measurements, and

(b) Determine the time delay for a laboratory experiment and the effects on the outputs caused by the decreasing of the input voltage.

An analysis was developed which simulates magnetometer measurements when the LOS of the magnetometer is not aligned with the principal spin axis. This technique was programmed and tested, and the results were compared with actual magnetometer measurements to see if this technique offers a solution to the type of motion exhibited by the actual magnetometer.

In addition, calibration reports for the magnetometers were reviewed. This study indicated that the Y magnetometer influenced the measurements of the X magnetometer (i.e., the X and Y magnetometer axes were not orthogonal).

An acceptable attitude for the EPP module was then determined utilizing the fact that the magnetometer axes were not aligned with the vehicle axes. Plots were generated displaying the comparison of the actual magnetometer measurements with those simulated using this attitude solution and a model magnetic field.

The final ECHO-EPP attitude was delivered on VAX-compatible magnetic tapes. In addition, software and associated documentation were delivered.

In addressing the second task described, four test cases were chosen for analysis. These cases were processed and the results suggested that the best approach in determining the time delay for specific voltages would be to average the read time differences. Linear least squares fits were done on the average time delay as a function of frequency (in KHz). Additionally, plots were provided which displayed both measured quantities versus fit quantities for each frequency and residuals as a function of frequency.

All results were delivered as required.

High Performance Booster

Task Description

This task was bi-phase. The first phase consisted of unpacking telemetry and digital data tapes and, utilizing bit manipulation and conversion, calculating selected parameters. The second part consisted of determining the attitude of the longitudinal axis of the vehicle (High Performance Booster (HPB)).

Tracking measurements recorded in an ASCII character set on a magnetic tape were unpacked and reformatted. Preliminary printouts and plots were produced. A comparison table was generated to compare positional data from the above tape to a provided-listing of Wallops smoothed tracking data.

The digital tape containing the telemetry data and Inertial Navigation System (INS) measurements was unpacked. The unpacking resulted in the creation of three CYBER 6250 BPI tapes. The time was quality checked, and all three tapes contained only minor dropouts. Each tape contained about 180 seconds of data, the first starting about 120 seconds before launch. The data rate on each tape was approximately 125 Hertz. Software was written to select bits and convert the data to its proper units by reformatting 12-bit data words into 16-bit or 32-bit measured parameters.

This completed Phase I of the project.

Phase II required the determination of the attitude of the vehicle axes, calculations of angles of attack with the vehicle velocity vector and the calculation of vehicle acceleration components. These attitude solutions were derived from both the MIDAS (ACS) and the INS data sets.

Accelerations were calculated using the velocity components on both the tracking data tape and INS data set. Attempts to curve-fit the Northerly, Easterly, and vertical positional components from launch to 100 seconds were initiated. Initial inspection indicated the need for piecewise curve fitting.

The attitude of the rocket axis was determined using the MIDAS measurements. The angle of attack between the rocket axis and the velocity vector was determined using the above attitude solution and the tracking data.

The attitude analysis for processing INS measurements was developed and programmed, and the results were presented to the user.

This concluded Phase II.

PSD Studies - Missing Data

Task Description

Develop software to estimate Power Spectral Density (PSD) values from sets of data with many missing data values.

The PSD can be estimated from either a set of data with no missing data values or from estimates of the autocovariance. Unfortunately, the data has a pattern in the set of missing data values such that even the estimates of the autocovariance have missing lag values. When there is a complete set of data Y_i ($i = 1, 2, ..., N$) then the estimates of the autocovariance usually used are

$$A(\tau) = 1/(N - \tau) \sum_{i=1}^{N-\tau} X_i * X_{i+\tau} = A(-\tau) \quad \text{(unbiased estimate)}$$

or

$$A(\tau) = 1/N \sum_{i=1}^{N-\tau} X_i * X_{i+\tau} = A(-\tau) \quad \text{(biased estimate)},$$

where

$$X_i = Y_i - \bar{Y}.$$

Here

$$\bar{Y} = 1/N \sum_{i=1}^{N-\tau} Y_i.$$

When there are missing data values, we have developed a procedure for estimating $A(\tau)$.

The following procedure was developed for estimating the desired PSD:

> Estimate $A(\tau)$ values for $0 \le \tau \le NMAX$ (NMAX usually 20). Fill in any $A(\tau)$ values for which no estimates were available using linear interpolation. Estimate the PSD of the $A(\tau)$ values using the BURG algorithm.

The PSD of $A(\tau)$ is then related to the PSD of the data values i.e., the PSD of the initial data is a constant times the square root of the PSD of the autocovariance. This procedure was used on the data provided and on simulated data with the same missing data values but with a known PSD. The procedure provides a good approximation of the actual PSD of the simulated data. This method will be documented for presentation and/or publication.

We attempted to increase the accuracy of the PSD estimates for many missing data values, by using the fact that the PSD of the actual data can be very closely approximated by a small set of low order reflection coefficients. This is an experimental fact found for most geophysical data. The reflection coefficients are quantities which allow the calculation of the autocovariance function for any lag. Thus, given a set of autocovariance estimates and the fact that only a small number of reflection coefficients are not equal to zero, we should, in principle, be able to estimate the set of reflection coefficients which fit the autocovariance estimates (in a least square sense). However, when there are missing estimates of the autocovariance, this is a highly non-linear problem. From the initial PSD estimate, we hope to calculate the values for the reflection coefficients which would approximately lead to the estimated PSD. An interactive procedure would then allow estimates of the best set of reflection coefficients, and from the estimates a new PSD would be calculated. The results of this method were used to estimate the accuracy of the results of the previous method by checking their consistency.

Software was written to apply the Lomb-Scargle periodogram to the sets of data with many missing data values. To check that the program works, a version of the program which simulates data without missing data points was written. The results indicate that the Lomb-Scargle periodogram method cannot find the PSD of red noise-type data if there are many missing data values. The problem is probably due to aliasing.

The software which estimated the PSD of a simulated set of red noise data with many missing data values by a weighted fit of the estimated autocorrelation function to a low order autoregressive model was modified. The modifications give the results due to a running sum as each file of data was processed. In addition, the results of the analysis, when the new estimate of the autocorrelation was used, were compared to the results one would obtain if an unbiased classical estimate of the autocorrelation was implemented.

The software was then modified to use the classical unbiased estimated of the autocovariance rather than the non-linear estimate of the autocovariance formerly used. The results of running the modified programs were similar to the results of running the original programs.

A third version of the software which estimate the PSD of a simulated set of red noise data with many missing data values was wrotten. This version replaces the red noise with a sine wave. The estimated accuracy for the frequency associated with this sine wave was then evaluated.

The results of these software versions were reviewed and described in a summary paper submitted (and accepted) to the Fifth ASSP Workshop on spectrum estimation and modeling in Rochester, New York in October of 1990.

Six sets of data (from Dr. Peterson in Colorado) were analyzed using a Blackman-Tukey type analysis to estimate PSDs. The data were analyzed using Burg's algorithm as found in Digital Spectral Analysis with Applications, by S. Lawrence Marple, Jr.

Four new data sets (taken at Pendelton) were provided for analysis. The four data sets contained data at a varying spacing with gaps. In order to find PSD estimates of these data sets, software was written to interpolate the data to form equally spaced data sets, but without compensation for the gaps. The method used consisted of fitting groups of four consecutive data points to a cubic and using the value of the cubic between the second and third values as an interpolated value. After interpolating the data segments to uniform spacing, PSD estimates were found using the Blackman-Tukey method. The results were then given to the Initiator.

Two additional methods were utilized. Gaps in the Pendelton data were filled-in by interpolation and the Burg algorithm was used to estimate a PSD. Burg's algorithm was also modified to handle gaps, and a PSD was run using this modified Burg algorithm. The results of these two types of analysis were different for high frequencies. The results of the Burg analysis was also somewhat different from the Blackman-Tukey analysis, previously used.

The Blackman-Tukey technique uses pre-whitening to form an approximate "white" spectrum before analysis and then post-darkens the result. In order to understand why the Burg and Blackman-Tukey techniques led to slightly different results, a new pre-whitening technique was programmed and implemented. The new technique used a filter which approximated the inverse of the filter implied by the Burg technique used on the data. The estimated PSDs using the Burg technique continued to be different from the PSD estimates derived from the Blackman-Tukey analysis. We assume the reason for this difference was that the Burg analysis used the data as separate blocks of data due to holes in the data sets, while the Blackman-Tukey method used all the points as a total data set.

Simulated noise which has a PSD versus frequency slope of S (S usually -2) above a read-in frequency was programmed to be the input to the programs which estimate the PSD of Pendleton's data. From runs of the simulated data, it was found that Burg's algorithm for estimating the PSD worked well. Blackman-Tukey's method, however, had difficulties finding the break frequency at which the S-slope no longer applied.

All Pendleton's data sets were processed using the programs which estimated PSDs. The programs which estimate PSDs, where the data was replaced by S-slope simulated data, were also run. These programs were run for $S = \{-3, -2.5, -2, -1\}$. The purpose of these various simulation runs was to understand how the missing data points found in

Pendleton's data affected the results. The results of the analysis were documented and presented as a paper by Edmond Dewan and Neil Grossbard at the AGU meeting.

PSD Studies - Estimate PSDs

Task Description

Develop software to help understand the behavior of geophysical measurements, by estimating PSDs, cross-correlation, and coherence measurements. Check the software by using simulated data which approximates the behavior found in the analyses.

Software was developed to estimate cross-correlation, coherence and phase relations between the three Pendleton temperature and intensity data sets. The method used was a Blackman-Tukey type analysis. The results were checked by running simulated data sets which have known cross-correlation, coherence and phase values. In particular, the results of the PSDs for each data set of temperature were plotted on a composite picture, and a weighted average slope and its standard deviation were found over the frequency range of interest. The weighting took account of the fact that there were differing numbers of data points with different spacings, etc. for each data set.

All the Blackman-Tukey analysis was done for various degrees of pre-whitening where:

$$Yf(t) = Y(t) - a\ Y(t+Dt), \text{ with}$$

Yf the pre-whitened data,
Y the original data equally-spaced (after some interpolation) at spacing Dt, and
a the parameter varied to set the degree of pre-whitening ($0 \leq a \leq 1$).

The data were also analyzed using Burg's algorithm. The two analyses were then detailed and presented to the initiator to be included in publication.

To further understand the results, the software were applied to simulated data. The simulated data used a pseudo-random number generator to simulate white Gaussian noise which was then filtered to simulate data with PSDs similar to the PSDs found in the analysis. Two types of filters were tried. One type of filter was a finite impulse response filter, found as a weighted least squares fit to data with constant slopes above a given frequency on a log-log plot of frequency versus power. The weighting was necessary so that the fit error was approximately constant in log-log space. The second type of filter was found as an infinite impulse response filter implied by the results of one of the Burg algorithm results.

Software was written to use numerical integration to find the theoretical effect of leakage in estimating the slope of a response curve with the following form:

(a) The response curve versus frequency was constant up to a first break frequency,

(b) the response curve then had a constant negative slope when considered in log frequency versus log response space from the first break frequency up to a second break frequency, and

(c) above the second break frequency, the response was again constant.

The results indicated that leakage had only a very small effect on the estimated slope. This implied that pre-whitening did not substantially improve the estimate of the slope in the Blackman-Tukey analysis. Further, software was written which took simulated Gaussian noise through a filter to approximate actual data with a given slope in log-frequency versus log-PSD space. The results were presented to the initiator.

Software was also developed to estimate the accuracy of the calculated slope of log-PSD versus log-frequency derived from simulated data which had a given slope. The program created the data with the expected slope by filtering random numbers, and then the software was run for 100 cases of the generated data. The results were originally consistent with the theoretical result found from the leakage program. When gaps were placed in the data, as occurred with the actual data, the results indicated that the slope estimates were effected.

The software to estimate coherence was modified to present estimates of the phase and the related time delay versus frequency. In addition, using methods suggested by Jenkins and Watts in "Spectral Analysis and its Applications", approximate error bars were placed on the coherence and phase versus frequency curves. The software was then run with Pendleton data and with two sets of Lowe data. In addition, a program was written to simulate data with a known value of coherence and phase. The program used two sets of random numbers, which were filtered to generate PSDs. The second data set was modified by adding a fraction of time-delayed values of the first data set. This procedure created data with a known coherency and phase distribution. The results indicated that the software did a good job of estimating the coherence and phase.

The software which estimates the coherence using autoregressive modeling sometimes lead to coherence estimates larger than 1. The problem was identified as having two possible causes. The first cause consisted of outliers in the data used in estimating the coherence. This was corrected by editing out obvious bad points in a data set. The other cause was associated with very low frequencies where the autoregressive techniques were known to be inaccurate.

Software was developed to simulate data with a constant slope of log-PSD versus log-frequency above a given frequency. The object was to observe what happens to the estimated PSD using a Blackman-Tukey type analysis as the number of input data points were varied. As expected, the low frequency behavior of the PSD estimates improved as the number of data points was increased. In addition, software, using the Burg's algorithm to estimate the PSDs, was developed using the same simulated data sets as the Blackman-Tukey analysis. The results were similar.

Software was written to divide scene 1 of the CIRRIS data into separate segments. Reflection coefficients and residual variance values estimated by Burg's algorithm were found for each segment. The PSD of each segment implied by these values was also estimated and plotted. The results were used to determine how the variance and reflection coefficients were varying with time. In addition, software to simulate data using the varying reflection coefficients and variances found from the original data of scene 1 was developed, several simulations were created, and their resultant statistics were analyzed. Also, software was written to apply a time-varying filter to the scenes of CIRRIS data. This showed that if a particular time-varying filter was applied to a CIRRIS data set, the resultant data looked like white Gaussian noise as determined by either a chi-squared or Kolmogorov-Smirnov test.

Another program was written to simulate data drawn from a distribution consisting of two different Gaussian distributions. The two distributions had different amplitudes and occurred at random times where the probability of the first distribution occurring was some number p, otherwise the second distribution occurs. These data were analyzed as were the CIRRIS scenes to try to whiten the data. The results indicated that a time-varying filter does not lead to white Gaussian noise for these simulated data.

PSD Studies - Turbulence Model

Task Description

Support efforts to model turbulence in the atmosphere, in order to understand its effect on laser propagation. The properties to be modelled were either the vertical shear or the value of wind velocity leading to this shear.

The models consisted of a set of sine waves (with random phases) which were functions of both the altitude and the horizontal distance. The amplitudes of the sine waves were designed to approximate the PSD (power spectral density) values usually estimated for the velocity or the shear in the atmosphere. Turbulence occurs when the shear exceeds a theoretical value.

Two types of models were tried. One type multiplied sines involving the altitude and sines involving the horizontal distance. The second type involved a set of sines involving the sum of frequency times altitude plus a related frequency times horizontal distance. Both models lead to some positions where turbulence occurs, but the second model better modelled the actual behavior.

In originally calculating the actual simulation, an FFT (fast Fourier transform), requiring evenly-spaced data, was used. It was found that, since the actual number of sine waves (in the second type of simulation) was usually less than 1000, an actual summation of the sine waves was a better method. In this method, the frequencies of the sine waves did not have to fall on the equally-spaced grid inherent when using the FFT.

The results of the analysis were plotted, including:

(a) The scene simulated,

(b) The continuous theoretical PSD in the horizontal and vertical directions, approximated by the model, and

(c) The results of estimating the average PSD from the simulated data in the horizontal and vertical directions from periodograms (using FFTs).

A more recent version of the model involved simulating the velocity with a set of sine waves equally-spaced in the altitude direction. The shear was then calculated from the simulated velocities. Software was written to simulate the shear rather than the velocity, by assigning phases to the sine waves from a pseudo-random generator such that all phases were (equally) likely between zero and two*pi. The amplitude of the sine waves was set by the model. These amplitude values were then multiplied by numbers found for a Gaussian white noise spectrum, which put a randomness in the amplitudes. The results were similar to those created when the velocity was simulated.

The latest simulation method involved inserting equally-spaced frequencies in the altitude direction. Since the resulting frequencies in the horizontal distance were too far apart, we used a large FFT in the horizontal frequency direction to simulate the data. This method was used since the number of horizontal values simulated was more than the number of altitude values, and the number of frequencies needed to get the desired frequency spacing in the horizontal direction approached 30,000. The results of this analysis were plotted as above.

Efforts were made to review smoke trail data to check the PSDs reported in the journal articles "Power Spectral Densities of Zonal and Meridional Winds in the Stratosphere" by E.M. Dewan, N. Grossbard, R.E. Good, and J. Brown, in *Physica Scripta*, Vol. 37, 154-157, 1988, and "Spectral Analysis of 10m Resolution Scalar Velocity Profiles in the Stratosphere" by E.M. Dewan, N. Grossbard, A.F. Quesada, and R.E. Good in *Geophysical Research Letters*, Vol. 11, No. 1, 80-83, January 1984.

Software using the latest analysis were written to regenerate the results reported. In particular, the software was used to investigate whether the results could be explained as due to low frequency sine waves rather than the results of noise filtered by the atmosphere. The results were not explainable by the sine waves.

UV Analysis - AIRS Database

Task Description

Maintain the Polar BEAR Auroral Ionospheric Remote Sensor (AIRS) data base files and associated computerized logs. Restructure the AIRS data bases into a VAX compatible format.

As summary tapes were received, computer routines were activated to quality check the tapes, augment the automated tape logs and reformat the tapes for processing on the Phillips Laboratory (PL) central site computer. Then the Auroral Ionospheric Remote Sensor (AIRS) data base routine was run on the reformatted data resulting in the creation of data base files and updated computerized logs. Generation of the AIRS data base continued routinely as new data were received. AIRS data base files were restructured into a VAX compatible format. Numerous files representative of the vehicle's lifetime were generated (at the user's request).

The AIRS instrumentation malfunctioned on May 6, 1989. To assist in the investigation of the cause of the problem, listings and files of relevant parameters were generated.

In order to allow viewing of AIRS data through use of a PC, a computer routine was modified for use on an IBM PC/AT. The routine reformats the raw telemetry data into an AIRS data base structure and computes ephemeris parameters from NORAD orbital elements. Numerous selected passes over the lifetime of the vehicle were processed. The resulting files were used for experiment analysis.

Several inquires were made regarding previously generated Polar BEAR AIRS data bases. The existing data base logs were updated and made available to interested experimenters, as requested.

The remaining processable Polar BEAR AIRS databases were restructured into a VAX-compatible format. Existing computer software was modified to perform this task on a tape-by-tape basis. The effort included 1657 selected files of data collected at the Sondrestrom, Tromso, and Rover stations over the lifetime of the vehicle.

VAX files of selected DMSP SSJ/4 electron and ion spectra data as a function of time and ephemeris were generated for comparison with corresponding Polar BEAR AIRS image data. The files and associated formats were provided to the experimenter.

UV Analysis - S3-4 Data

Task Description

Generate VAX-compatible tapes containing selected words of pre-processed spectrometer and photometer data collected by the S3-4 satellite for specified orbits. Orbits being of a format C-type, A-type or short in nature require pre-processing applications prior to the final tape creations.

VAX-compatible tapes containing selected words of pre-processed spectrometer and photometer data collected by the S3-4 satellite for specified orbits were generated for in-house analysis.

Software, required to pre-process S3-4 raw spectrometer and photometer data, was created and tested. The pre-processing includes the generation of data bases and laser plot displays of instrument count data as a function of time and selected ephemeris parameters for various wavelength constraints.

All processable orbits of data were pre-processed and restructured into VAX-compatible tapes. In addition, two VAX-compatible tapes containing 5 orbits of special interest of selected words of pre-processed photometer and spectrometer data were generated for off-site analysis.

UV Analysis - HUP Experiment

Task Description

Create software to process the Horizon Ultraviolet Probe (HUP) experiment flown on a space shuttle mission. Process Charge-Coupled-Device image data from a Barium-cloud tracer experiment.

Meetings were held with the PI to discuss the overall data flow for the HUP sensor flown on a shuttle mission. File formats were defined which accommodate the data type independent of the record format.

A trip to Lockheed was taken in order to finalize details on techniques and formats of the raw flight data. A sample tape in these formats was shipped to Phillips Laboratory (PL). In addition, the reformatted file structures for the HUP sensor were finalized. The development of software to input the Lockheed data and produce the structured HUP files was initiated.

The development of the software to input the Lockheed data and produce masterframe formatted HUP file structures was completed, and the software was tested using a simulated data file produced by Lockheed.

The processing was begun for interpretation of Charge-Coupled-Device image data from an experiment designed to elucidate the structure of the Earth's magnetic field by recording the ultraviolet emissions from an artificially introduced Barium-cloud tracer.

IMAGE and FLAT-FIELD files were converted into byte format, for compatibility with the experimenter's image-processing hardware. An IMAGE file, with the FLAT-FIELD background data removed, was created. The resulting image was then displayed in conjunction with a set of intensity profiles (cuts through the image, both centered at the peak value of the Barium cloud's emissions and offset from the peak).

CRRES E-Field

Task Description

Develop analyses and software to process the CRRES Langmuir probe telemetry data to generate spinfit coefficients for each spin period. Store the coefficients and associated parameters in a database for future analysis.

Studies were performed on spin fit coefficients derived from the CRRES vehicle cylindrical booms. These studies involved the determination of maximum and minimum time and E-Field values for each set of spin fit coefficients.

Meetings were attended with the Langmuir Probe PI to discuss spin fit coefficient, E-Field and magnetometer data. Due to the way that the spin fits were presented by telemetry, the precise time tagging of the start of a spin fit period was examined. Several procedures were tried in an attempt to resolve inconsistencies.

Updated calibrations and procedures were presented for the mapping of the spin fit cylinder coefficients into mV/m units. To aid in determining proper V×B subtraction procedures, the PC-hosted data base was generated for specific time intervals, and selected parameters were displayed using an independent PC-hosted graphics package. A number of ancillary parameter data bases were generated. Selected parameters from these data bases were displayed using PC-hosted graphics routines in order to assist in the interpretation of the data.

A detailed flow of data for the computation of ground-based spin fits was developed. This included the determination of analytic techniques to produce one set of coefficients per vehicle spin. The start time for each fitting period was the same time which was used in the on-board computations. Displays and listings of the spin fit coefficients for both the cylinders and spheres were produced for analysis.

The flight data spinfit processing consists of a two-phased approach. Phase-1 software consisted of transporting the telemetry and associated log information, ephemeris and attitude data from various optical disks resident on a PC to the optical disk library system. Phase-2 software accessed the telemetry data and produced an ASCII Berkeley data file of selected parameters, associated these data with corresponding attitude and ephemeris data (found in separate files), determined the spinfit coefficients and then stored these data on the UNIX optical disk library system for further analysis.

Phase-1 processing of CRRES Langmuir probe data was completed. Phase-2 processing was accomplished on several hundred orbits.

EXCEDE III Attitude and Trajectory Determination

Task Description

Determine the trajectory of the Booster, Accelerator and Sensor modules of the EXCEDE III vehicle using the tracking information. Then determine the attitude for the lines-of-sight of various instruments on-board the Sensor and Accelerator Modules.

Digital tapes containing raw tracking data for the three EXCEDE III modules were received. Software was written to unpack, reformat and quality check the tapes containing the attitude data for the Sensor and Accelerator modules. CYBER-compatible data bases were created for each module and each radar, and individual positional parameters were displayed and evaluated. Based on this evaluation, Radar 124 (beacon-track) was selected for the Motor module, Radar 128 (beacon) for the Sensor module and Radar 127 (skin) for the Accelerator module. The raw data bases were then reformatted to run in the Phillips Laboratory (PL) Trajectory Processing System. The results for the two beacon-tracked modules were acceptable. Processing of the data for the Accelerator module required some additional effort.

Sensor and Booster Modules

In response to additional requests for trajectory processing, Sensor radar data were curve-fitted in three segments. The first was for the full flight, the second fit was to just before payload separation and the third fit was made from payload separation to the end. Down-range velocity and cross-range velocity were provided. In addition, Booster radar data were curve-fitted to polynomials in two segments: one to just before separation, and the other, from payload separation to the end. In all cases, fourth-order polynomials fits were used.

Lines-of-sight attitude were determined for eight instruments on the Sensor module, and plots and listings of the Sensor module's ACS nozzle firings and in-flight calibrations were generated.

Accelerator Module

Accelerator module radar data were curve-fit, and continuous results for the slant-range, azimuth, and elevation were generated for the period 175 to 240 seconds after launch.

Calibration information were received for the Attitude Control System (ACS). These data were utilized for least squares fits as a function of voltages; the results were converted to degrees; magnetometer outputs were converted to milligauss; and the angles between the theoretical magnetic field vector and all the required lines-of-sight on the Accelerator module were determined. Magnetic pitch angles for lines-of-sight for the magnetometers were also generated from the magnetometers themselves, and they were compared with simulated angles derived from attitude and model magnetic fields, showing magnetometer alignments with the vehicle axes. No corrections were made for permanent or induced fields in these calculations. Associated plots and listings were also supplied.

The model magnetic field for the entire mission was determined, based on IGRF 1985 coefficients. The elevation and azimuth of the three vehicle axes and the gun axis were listed and plotted, along with actual magnetometer measurements.

CRRES Time History Data Base

Task Description

The task presented was to re-host the CRRES Time History Data Base (THDB) generation software from the CYBER computer to the VAX/VMS system for Aerospace and Berkeley sensors.

The effort chosen involved the Aerospace Corporation sensors. Program modifications for re-hosting were performed on the Medium Energy Electron Spectrometer (MEES), the Electron Proton Angle Spectrometer (EPAS), the Proton Switches, the Relativistic Proton Detector, the Magnetospheric Ion Composition Sensor (MICS), the Low Energy Magnetospheric Ion Composition Sensor (LOMICS), and the Heavy Ion Telescope (HIT).

The VAX versions were compiled, linked and successfully run using data from three orbits. Final validation was accomplished by means of bit-by-bit comparisons of the new output files with those previously generated using the CYBER-hosted software.

Next, re-hosting of the one second and one-spin-cycle THDB files generated for the Electric Field package were completed. In addition, the Passive Plasma Sounder and Searchcoil Magnetometer THDB generation routines were re-hosted to the VAX/VMS system.

Finally, the Berkeley Log File and the Berkeley Agency Tape for C-language routines were completed. File validation procedures were successfully performed.

All software and documentation were delivered as required.

APEX Support

Task Description

Gather requirements and define file structures for the APEX Agency Tape generation Orbital Data Processing (ODP) system. The sensor packages involved in this mission consist of PASP+, Dosimeter, CRUX, CREDO, and FERRO. In addition, develop appropriate sections of APEX Data Management Plan (DMP), and provide support as Experimenter Interface.

Documentation was reviewed on the mission, spacecraft, sensors, telemetry system and data recorder. Several meetings were held with various APEX experimenters to discuss their particular Agency Tape file structures. In addition, trips were taken to Orbital Sciences Corporation (OSC) and the Naval Postgraduate School (NPS) to gather information on mission requirements, and a second trip was taken to OSC to attend the APEX CDR.

A Preliminary Design Review (PDR) for the APEX Orbital Data Processing System (ODPS) was held at Phillips Laboratory (PL/GPD). File formats for nearly all agency files were defined and presented at the PDR.

Sections of the APEX DMP were written and reviewed with the APEX Data Manager, including downlink telemetry structure as well as output file structures.

As test files of APEX Agency Tape data were generated, the process of validating the files for both structure and content took place. The files used for testing contained both anomalies and time overlap.

A trip to Aerospace Corporation, Sunnyvale, CA was taken to attend the Mission Operations Working Group (MOWG) meeting #8. Briefings were given on all APEX sensor packages. The System Level Test Procedures document to be used in conjunction with the end-to-end testing was reviewed.

The Agency Tape Generation end-to-end test was successfully run, and all files were found to be valid and structured to the specifications of the Data Management Plan. As spacecraft testing continued, a number of additional APEX Agency Files were received for validation. These files were generated from tapes acquired during spacecraft testing. All files received complied with Data Management Plan specifications.

A trip was taken to the Space and Missile Command (DET2/SMC) to discuss the concept of using electronic mail as a means of product transmission. Agreement was reached on the methodology for transmission and the procedure was successfully tested.

NASA Products - GLO Mission

Task Description

This effort consists of re-hosting (from the CYBER to the VAX computer) software developed for the pre-processing of NASA data products.

Re-hosting (CYBER to VAX) of NASA product software was concentrated in two areas:

(a) the Post Flight Attitude and Trajectory History (PATH) product, and

(b) the orbiter ancillary file generated from the User Calibrated Ancillary Tape (UCAT).

Sample files from the PATH (full data set) and UCAT (for water dump files) were generated. After software modification, these files were successfully compared to the files generated from mission STS-39.

The re-hosting effort was completed with respect to the UCAT Ancillary Data File, RELBET, and COSTA-4 for thruster firings. The effort to adapt the UCAT to permit Parent/Child word extraction (since UCAT tapes following STS-39 have contained these parameters) of the thruster information was completed. UCAT Ancillary, RELBET, and Thruster Firing files were generated and successfully validated by direct comparison with files previously generated for STS-39.

APEX/PASP Plus Time History Data Base

Task Description

Develop a Time History Data Base (THDB) generation system for the Photovoltaic Array and Space Power - Plus Diagnostics (PASP Plus) sensor package. The PASP Plus sensor was flown on the APEX spacecraft.

Meetings were held with the APEX Principal Investigator (PI) to discuss general structures to be used in the THDB architecture and details of each of the sensor packages, including telemetered data sets and sensor operations for the PASP Plus package. These discussions have resulted in the development of preliminary THDB file structures for Ephemeris and Attitude/Magnetic Field files. The preliminary parameter sets to be included in the THDB structures for the Electrostatic Analyzer, Langmuir Probe, Housekeeping/Sun Sensor/Contamination, Spacecraft State of Health, Emitter, Dosimeter, Transient Pulse Monitor, Leakage Current, and IV (current-voltage) files were also defined.

Technical meetings were held with the APEX PI to discuss details of sensor operations and their relationship to telemetry parameters. These meetings resulted in the definition of the structures for the THDB architecture of the 16 solar panels and the Langmuir Probe pre-process files.

The preliminary THDB file structures for the Electrostatic Analyzer, Langmuir Probe, Housekeeping/Sun Sensor/Contamination, Spacecraft State of Health, Emitter, Dosimeter, Transient Pulse Monitor, Leakage Current, and IV (current-voltage) parameter sets were completed.

DMSP Analysis - Evaluate SSIES

Task Description

Evaluate and modify the Air Force Global Weather Central (AFGWC) Special Sensor for Ion, Electrons and Scintillation (SSIES) analysis software, for comparison to the Phillips Laboratory (PL) analysis techniques and as a baseline for utilization with forthcoming Defense Meteorological Satellite Program (DMSP) satellites incorporating different data inputs.

The developmental plan for evaluation and modification of the AFGWC SSIES analysis program was defined. Source code listings were analyzed for modifications required to perform the AFGWC analysis for the SSIES instrument package at PL. Input and output routines specific to the AFGWC UNIVAC computer were identified and examined. Input routines were replaced by routines designed to acquire the data from the PL PHASE-I format. The output emulation software, needed to match the current PL PHASE-II output format, was designed.

A LDCON emulation was developed to provide the operating parameters and conversion constants to the SSIES program in the required format. The program parameters required modification for the SSIES-2 development, due to changes in the telemetry data content. Parameters provided in the SSIES documentation were used with LDCON to generate the appropriate specification file for the PL version of SSIES. Diagnostic-enabling parameters associated with LDCON were modified, as appropriate.

The software required to synthesize SSIES-2 testing data from augmented SSIES data was developed to accommodate particular time, cycle, and command conditions. The associated data acquisition module for SSIES-2 was also developed. An appropriate set of input parameter specifications was determined for SSIES-2, and a revised LDCON program for reformatting these parameters was completed.

The SSIES-2 processing code was then tested and debugged using the appropriate set of SSIES-2 input parameter specifications which were formatted by the LDCON program. The results were compared with the results of the PL version of the SSIES program. Analysis of the outputs from the SSIES-2 tests showed that the various experiments' processing results were consistent with the results of the PL version of the SSIES program.

The SSIES-2 software and data files were stored on magnetic tape, and a description of the tape contents was provided. The SSIES-2 report, including an operational description for the software and an overview of its structure, was completed.

Publications

J.R. Cornelius, K.P. Larson and A.J. Mazzella, DMSP SSIES-2 Data Processing Program: User's Guide, PL-TR-91-2190, ADA243951.

DMSP Analysis - Modify SSIES-2

Task Description

Modify the Special Sensor for Ion, Electrons and Scintillation (SSIES)-2 processing system for utilization on VAX systems at both Phillips Laboratory (PL) and Space Forecast Center (SFC).

The SSIES-2 data processing system, developed at Phillips Laboratory for use on the CYBER and subsequently modified at Space Forecast Center for use on a VAX, was installed on the Phillips Laboratory VAX/VMS system. Using the synthesized SSIES-2 input data sets from the original CYBER development, the software was tested, modified and retested until the results exactly matched the results from the CYBER-based system.

Preprocessor software, to convert PL DMSP THDB values into a format compatible with SFC input data requirements, was developed and tested. Similar software with identical output, but with AFGWC input data rather than the PL DMSP THDB input, was developed for SFC. SSIES-2 was enhanced to use the common input format, to implement required changes in the outputs and to eliminate all GWC system specific outputs.

Test runs of the SSIES-2 processing program were performed using inputs from both the PL preprocessor and the SFC preprocessor. The results were analyzed, some processing constants were revised, and the runs were repeated. The second set of results correlated favorably with results from an independent source.

Enhancements were made to the experiment sections of SSIES-2 to allow for more accurate processing of SSIES-2 data. In addition, plots and tabular results were created.

The SSIES Programmer's Guide and the Software Maintenance Manual (Volumes 2 and 3 of the SSIES User's Guide) were completed.

Publications

A.J. Mazzella and J.R. Cornelius, Data Re-Formatter Program for the Topside Thermal Plasma Monitor (PLIESPP), RDP-TR-9403, 1994, PL-TR-94-2278. **ADA290960**

J.R. Cornelius and A.J. Mazzella, User's Guide for the Topside Ionospheric Plasma Monitor (SSIES, SSIES-2 and SSIES-3) on Spacecraft of the Defense Meteorological Satellite Program (DMSP): Volume 2, Programmer's Guide for Software at AFSCF, 1994, PL-TR-94-2270. **ADA290913**

J.R. Cornelius and A.J. Mazzella, User's Guide for the Topside Ionospheric Plasma Monitor (SSIES, SSIES-2 and SSIES-3) on Spacecraft of the Defense Meteorlogical Satellite Program (DMSP): Volume 3, Program Maintenance Manual, 1994, PL-TR-94-2271. **ADA290941**

Langmuir Probe Analysis

Task Description

Develop analysis and evaluation capabilities for the CRRES Langmuir probe, in conjunction with the definition of the Time-History Data Base (THDB). Implement processing algorithms and data selection criteria, based on user specifications.

Software for the plot pre-processing, based on the requirements and interfaces for the CRRES data, were developed. These procedures define the acquisition of data from the magnetic field, electric field, ephemeris, attitude and calibration files, for the generation of a composite database. Attitude determination software was incorporated into these procedures. Plotting software was developed for the display of electric field, magnetic field and sensor quantities.

A further effort involves the development of analytic techniques and associated software for the study of CRRES data from the Berkeley and Iowa sensor packages. Agency and Log file structures were integrated into graphics packages for the display of raw sensor outputs. Displays were validated by correlating outputs with those produced at Berkeley using calibration data. Similar procedures were employed using sensor data for flight data.

The implemented algorithm for representing the spin-fit electric field data was changed to accommodate the lack of valid data for the sphere booms. The replacement algorithm had been developed to allow independent representations of the electric field for the sphere and cylinder booms.

Two additional versions of the pre-processing program were developed to provide the V×B and 1-second E-Field data values in alternate forms from the GSE coordinates originally specified. One version provides this data in the spin plane (MGSE) system, while the other operates on the data in the Earth-Centered Inertial (ECI) coordinate system and gives special scalar output values in volts. An alternate version of the plotting program was also developed. The results are being analyzed.

Software to process the electric field probe data to generate the spin fit databases was completed and tested, using solution routines migrated from the VAX to the GPSG SPARCstation. Additional provisions were incorporated into the program to generate intermediate results to be used for verification purposes. Discrepancies in coefficient values were traced to the SPARCstation FORTRAN compiler, and after modification, results correlated. Software was/will be released for production processing.

Plasma Calculations

Task Description

Develop software to study the motion of charged particles in a self-consistent electrostatic field and an imposed magnetic field. Software to display electrostatic potentials and particle distributions were also required. The software structure was required to be consistent with the requirements of multiple host computers (CONVEX or VAX).

The basic software for the electrostatic potential calculation was developed, consistent with the requirements of multiple host computers. In addition, basic test case density specification software was developed for use with the potential solver. These were used to perform analysis tests on the CONVEX.

The original potential solving algorithm, however, failed for axi-symmetric, longitudinally-symmetric modes. A revised potential solving algorithm was therefore developed. In addition, software was developed to utilize a variable radial grid spacing, instead of the previous uniform grid spacing, by incorporating a generalized formulation of the potential solver expressions.

Test software was developed to convert arrays of particle positions to density representations on specified grids and to allow general specification of radial, azimuthal, and longitudinal density distributions. These software were used to exercise eight density distribution cases to test the potential solver.

VAX IDL plotting procedures were implemented to acquire data produced on the CONVEX and generate contour plots on the VAX mainframe or a VAX workstation. In addition, an IDL procedure was developed to plot potential (or density) versus a single specified independent-variable grid index for selection of a particular cross-section of data. This procedure displayed up to three labeled plots on a page. Later, revisions were made to produce multi-panel contour plots on a single page and to allow specification of radial grid values within the data files.

Finally a VAX version of the numerical potential solver program was implemented to use the Digital eXtended Math Library (DXML) Fast Fourier Transform (FFT) routines. These were later revised by incorporating code based on the Numerical Recipes one- and two-dimensional FFT methodology.

The final, delivered software, including potential calculations, density determination, and plotting for potentials and densities, contained no machine-specific code.

QINMS Data

Task Description

Reformat the Quadrupole Ion Neutral Mass Spectrometer (QINMS) data, flown on-board the STS-4 orbiter, into a VAX-compatible file structure. Generate attitude data for the QINMS experiment, and generate ASCII-structured files of specified QINMS database parameters for several orbits of data.

Software was developed, debugged and tested for the reformatting effort. All tapes received were successfully reformatted, and the resulting files stored on disk.

The vehicle's attitude angles of pitch, yaw, and roll were expressed in three coordinate systems: Local Vertical Local Horizontal (LVLH), an inertial Mean 1950 coordinate system (M50), and an inertial true of date coordinate system (TOD). Using the pitch, yaw, roll Euler sequence, a matrix representation of the main vehicle's axes was determined.

It was necessary to transform the magnetic field vector from its local Cartesian system (inclination and declination) to the TOD. Once completed, the angles which the magnetic field vector made with the LOS of the experiment and also with the Orbiter's primary axes were determined. Based on these analyses, the required attitude parameters for specific points of interest in the lifetime of the mission were generated.

Software which access the QINMS database were developed and utilized to extract selected parameters and create ASCII-structured files. These ASCII database files contain corrected currents for all masses and grid values in the neutral mode.

The final attitude analysis procedures were developed and integrated into the QINMS attitude generation system. This software system was used to generate final attitude for several selected intervals over the lifetime of the mission.

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